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DDT APPLIED AGAINST CERTAIN FOREST INSECTS IN 1944, PARTICULARLY WITH AERIAL EQUIPMENT

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For a number of years the Bureau of Entomology and Plant Quarantine has been testing the effectiveness of certain insecticides against the gypsy moth (Porthetria dispar (L.)). Insecticides have been applied both from the ground and from aircraft. During 1944 this work was continued, most of the experimental plots being laid out in northeastern Pennsylvania. In April about 150 pounds of DDT (1-trichloro-2, 2-bis (p-chlorophenyl)-ethane) were made available for experiments against the gypsy moth, and it was decided to use the insecticide to treat one 20-acre plot of woodland from the air and several smaller plots with ground equipment. The airplane application was so successful that during the course of the season, as more DDT was made available, similar applications were made against a number of other forest insects. The treatments were all made on a small scale, but the results were very promising. This paper summarizes the season's work, and briefly describes the distributing apparatus used in the airplane applications.

FORMULAS USED IN MIXING DDT

For application by means of ground equipment an emulsion was made up by mixing 1 pound of DDT, 1 pint of cyclohexanone, and 4½ pints of Shell horticultural spray base heavy oil, and then adding an emulsifier, IN-2503 (an oil-soluble alcohol sulfate product), at the rate of 2/3 gallon, and 1 quart of alcohol, per 100 gallons of final tank mix. The emulsion concentrate was diluted with an equal amount of water and then poured directly into water in the spray tank. This emulsion was very satisfactory in that it showed what results could be expected with an emulsion. However, this particular formula is too expensive to be practical, and cheaper materials will be used in future tests.

A suspension made up of DDT, 2 parts and urea resin glue 1 part (by weight) was also applied with ground equipment. The materials were mixed dry after the DDT had been sifted through a fine-mesh wire screen. Water was added slowly until a thin slurry was obtained. The slurry was added to the agitated water in the spray tank. The mixture clogged the strainer in the spray line between the tank and the pump after about 300 gallons had been applied. This could probably be avoided if a similar suspension were desired for further experimental purposes.

Sprays Applied from Aircraft

Sprays to be applied from aircraft were mixed according to formulas given in table 1. In each case the DDT was dissolved in the solvent and then the oil was added. As a rule the DDT dissolved readily, but at times considerable agitation was necessary before it was completely in solution. During 1944 small lots were mixed in a 20-gallon drum, and an electric mixer was used for stirring. Large lots were mixed in a power sprayer. In all the sprays containing xylene this solvent was used at the rate of 1½ pints to 1 pound of DDT. Unusually warm temperatures at the time these sprays were mixed undoubtedly helped to dissolve the DDT, but as a general rule it may be advisable to use 1 3/4 or even 2 pints of xylene to 1 pound of DDT. Sprays were strained to remove foreign matter. All the sprays were complete solutions except the one containing only DDT and kerosene, which was a partial suspension and therefore required constant agitation during spraying. When completely dissolved the DDT apparently remained in solution until after the spray was deposited; at least an examination of glass plates put out in sprayed areas indicated that DDT crystals first appeared after the oil had begun to evaporate.

GROUND APPLICATION

Laboratory experiments indicated that DDT failed to prevent gypsy moth egg clusters from hatching, but that the mortality of newly emerged larvae was heavy when they crawled on treated twigs. Plans were made, therefore, to apply DDT with ground equipment to certain plots before hatching took place and to others during larval development.

In one experiment 12 apple and 5 willow trees on a small farm in the township of Spring Brook, Pa., were treated with an emulsion containing 3 pounds of DDT per 100 gallons of water. During the winter months approximately 19,500 gypsy moth egg clusters on these trees and on a stone wall in the immediate vicinity were treated with creosote. Since the wall was not taken down, several thousand egg clusters in the interior of the wall were not treated. The emulsion was applied to these trees just prior to the first hatch. Many egg clusters, however, owing to their protected positions, did not hatch until at least 2 weeks later. Some gypsy moth larvae completed development, and 6 new egg clusters were found on the trees at the end of the season. It is believed that some of the late-emerging larvae were unaffected because of loss in the residual toxicity of the insecticide.

In another experiment treatments were applied to four 1-acre and two 1/2-acre woodland plots. Three of the 1-acre plots and two 1/2-acre plots were treated with a DDT emulsion similar to that applied to the apple and willow trees. Complete control was effected on all of them. From a few days after the spray was applied until the end of the season no living larvae were observed within the plots, and in the fall no new egg clusters were observed. One of the 1-acre plots was treated prior to hatching of the eggs with a dosage of 3 pounds of DDT per 100 gallons of water. Since 270 gallons of spray were used, about 8 pounds of DDT were applied. The other plots were treated at concentrations of 1 to 3 pounds of DDT per 100 gallons, or with 4 to 12 pounds per acre, when larvae were in the fourth and fifth stages. Cryolite was added to the DDT emulsion on one plot, but there was

indication that it increased the toxicity of the spray. In all cases larval mortality was very high immediately following application. Tests with caged larvae showed that treated foliage also retained its toxicity for a considerable period. Fifty fifth-stage larvae that had been caged with foliage treated at the rate of 4 pounds of DDT per acre 10 days previously and after 1.62 inches of rain had fallen were all dead within 6 days. Since very little foliage was fed upon, mortality was no doubt caused principally by contact with the sprayed foliage.

No foliar injury was evident on the plot sprayed before the eggs hatched (just as buds were bursting) but rather severe burning occurred on the plots sprayed later in the season at the rate of 3 pounds of DDT per 100 gallons. All evidence indicated that burning was caused by the amount of oil used and not by the DDT. Where only 1 pound of DDT per 100 gallons was used, and therefore about one-third as much oil, injury was very slight. Since complete control was effected at the low concentration, it is believed that foliar injury can easily be avoided in future applications.

The fourth 1-acre plot was treated with DDT mixed as a suspension and applied just prior to hatching. Urea resin glue (Weldwood) was used as a sticker. About 6 pounds of DDT per 100 gallons were used. The material went on very nicely, and tiny particles of DDT were plainly visible on the bark of the trees. In spite of a 1.5-inch rainfall the night following application and 0.25 inch of rain 9 days later, the insecticide adhered very well. Nevertheless, a considerable number of gypsy moth larvae survived and completed development. Counts in the fall indicated the presence of 261 new egg clusters per acre. There had been 418 per acre in the spring.

AIRPLANE APPLICATION

Distribution

DDT in oil sprays can readily be distributed from airplanes. Two planes have been used for this work against forest insects[1]. One of them, a Piper Cub capable of carrying approximately 200 pounds of pay load, was used to treat 5 acres infested by the gypsy moth in the township of Greenfield, Saratoga County, N. Y. The liquid spray was released under pressure from a series of six nozzles attached to a cross pipe under the fuselage. A White standard biplane with a capacity of about 800 pounds pay load was used for all other applications. For this type of work it was flown at a speed of about 80 m.p.h. at a height about 50 feet above the treetops (fig. 1). The plane was equipped with a distributing device that was developed by the Division of Gypsy and Brown-Tail Moths Control[2] at Greenfield, Mass., primarily for distributing concentrated suspensions of lead arsenate and

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[1] The junior author Donald Whittam piloted the planes in all applications made in 1944.

[2] W. H. Campbell and Donald Whittam are responsible for perfecting this apparatus.

cryolite. The device also worked admirably for oil sprays containing DDT. Its essential features (fig. 2) consist of two units of four disks each, set at each side of the fuselage and just outside the slip stream, which are rotated by small air-driven propellers. At 80 miles an hour these disks turn at about 2700 r.p.m. The spray mixture is fed by gravity onto these disks from a tank within the plane. As the liquid is thrown off the rapidly revolving disks, it is broken up into a finely atomized mist.

Test flights over the airport showed that under still weather conditions the mist settled down over a swath about 150 feet wide, whereas a very light breeze increased the width of the swath to about 200 feet. There was rather light coverage at the extremities of the swath, and as a certain amount of overlapping was considered advantageous, the effective width of the swath was figured as 120 feet in calculating the desired rate of spray flow. If a strip 120 feet wide is covered at 80 miles per hour, about 20 acres are treated per minute. The distributing device was therefore adjusted to deliver 20 gallons of spray per minute (10 gallons per unit). This was about the maximum output possible with the distributing device as operated in 1944; so when 2, 3, or more gallons per acre were applied the areas were covered two, three, or more times. When less than 1 gallon per acre was used, the device was adjusted to deliver the proper amount. When 1 gallon per acre was distributed during test flights over an open, flat surface, about 90 droplets fell per square inch of sprayed area. Droplet size ranged from 20 to 680 microns in diameter, with an average size of 178 (24 percent of the droplets were from 20 to 100, 37 percent from 100 to 200, 27 percent from 200 to 300, and 12 percent more than 300 microns in diameter).

In the actual spraying operation the completeness of coverage obtained throughout an area depends largely upon the experience and flying ability of the pilot, and to a lesser degree upon a good system of marking. The area to be treated is marked by windsocks or other suitable markers. During application the pilot checks the amount of insecticide to be distributed against the number of acres in the area to be flown, and governs his progress accordingly. Owing to the extreme unevenness of the terrain and the variation in density of forest foliage, the pilot varies the spacing of his spraying runs and by so doing controls the dosage to treat suitably the leaf surface below him. Obviously an inexperienced pilot may cover a considerable portion of some strips twice and miss some areas entirely, but as experience is acquired these errors will be reduced to a minimum. The pilot will always be confronted with wind drift and convection currents in the air, as well as physical obstacles on the ground. He will have to judge to what extent these atmospheric and ground conditions are affecting the application of the insecticide and be guided accordingly.

In one test at Litchfield, excellent control was obtained for a width of 55 feet when one swath of insecticide was laid down, and for a width of

158 feet when two over-lapping swaths were applied. The fact that control was not obtained over a wider strip when one swath was applied may not be particularly significant, for this was the only test of its kind that could be satisfactorily observed during 1944. Nevertheless, it may indicate that there is a comparatively light deposit of spray on the edges of a swath, and perhaps it is advisable to fly over an area twice in order to get an even, satisfactory distribution of insecticide.

During 1944 actual spray deposit was estimated by placing 6-by 6-inch glass plates on the ground throughout the treated areas and examining them for deposit of DDT crystals. Very good coverage was obtained in mixed hardwood growth when 3 gallons of spray was applied per acre. Good coverage was obtained in young red pine plantations when 1 gallon per acre was used. Dense coniferous growth showed poor ground coverage even where 5 gallons per acre was distributed. Gallonage of spray per acre must obviously be varied according to the area, density, and type of foliage to be covered.

Tests for the Control of Forest Insects

Treatments made during 1944 are summarized in table 1. Complete control was obtained against the gypsy moth, the green-striped maple worm (Anisota rubicunda (F.)), and the red-headed pine sawfly (Neodiprion lecontei (Fitch)).

The results against the gypsy moth were particularly gratifying, for they showed that control could be obtained if applications were made prior to hatching of the eggs or after the larvae were partly developed. The first treatment was made in the township of Jefferson, Lackawanna County, Pa., on May 3, when a plot of 20 acres was sprayed. This was just prior to gypsy moth hatch, and gray birch buds were just bursting. On May 6 and 7 there was a heavy rainfall of 1.5 inches, and on May 15 another 0.25 inch of rain fell. Hatching of gypsy moth eggs was general on May 8. Apparently all larvae were killed upon coming in contact with DDT crystals, either on the egg clusters or on surfaces nearby, for no larvae were observed feeding on foliage throughout the season. In the fall an extremely careful check for new egg clusters was made throughout the 4 acres that had been most heavily infested (counts made on a sample plot had indicated a population of 1,359 egg clusters per acre in the spring), and not a single one was found. A 5-acre plot at Greenfield, N. Y., was treated when gypsy moth larvae were in the second and third stages and the trees were well foliated. Results were equally as good as those obtained at Jefferson. Both these areas were treated at the rate of 5 pounds of DDT in 5 gallons of spray liquid per acre.

The same dosage was applied to young larvae of the green-striped maple worm at Derby Line, Vt. The area treated was composed mostly of large, widely spaced maple trees, but some beech trees were present. On this plot the larval mortality was high, not only of this species but also of Anisota virginiensis (Drury) on beech and Heterocampa spp. on both maple and beech. Although no final check has been made, excellent control of the green-striped maple worm was indicated.

Table 1.--Summary of tests with DDT applied by airplane against forest in 1944

Date	Area treated	Insect	Formula: DDT 1 pound plus: accessory materials as indicated	DDT per acre	Spray per acre	Results
	Acres		Pints	Pounds	Gallons	
			Cyclohexanone 1 plus:			
May 3	Jefferson, Pa., 20	Gypsy moth (prior to hatch)	Shell oil 7	5	5	Complete control
24	Greenfield, N.Y. 5	Gypsy moth (second and third stages)	7	5	5	Do.
June 27	Algonquin Park, Ont.	Spruce budworm (mostly pupae)	Mentor No.28 oil			
	8		6.4	5	5	Results cannot be given until 1945, but high population of living overwintering larvae present
	12.8		9	3	4	
	9.6		14	2	4	
30	Brasher, N.Y.	Red-headed pine sawfly (mostly larvae)				
	5		Shell oil 7	5	5	Complete control
	11		10	$2\frac{3}{4}$	$2\frac{3}{4}$	Do.
July 7	Derby Line, Vt., 8	Green-striped maple worm (larvae)	10	5	7	Do.
			Xylene $1\frac{1}{2}$ plus:			
Aug. 14	Pittston, Pa., 40	--- 1/	Shell oil 6.5	5	5	
Sept. 16	Litchfield, Conn.	Imported pine sawfly (larvae)				
	2 swaths		6.5	2	2	Good: perhaps complete control
	1 swath		6.5	1	1	Considerable kill
			13	$\frac{1}{2}$	1	Slight kill
			6.5	$\frac{1}{2}$	$\frac{1}{2}$	Do.

1/ To determine the effect on water and wild life.

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June 27	Algonquin Park, Ont.	Spruce budworm (mostly pupae)	Mentor No.29 oil			
	8		6.4	5	5	Results cannot be given until 1945, but high population of living overwintering larvae present
	12.8		9	3	4	
	9.6		14	2	4	
30	Brasher, N.Y.	Red-headed pine sawfly (mostly larvae)	Shell oil 7			
	5			5	5	Complete control
	11		10	$2\frac{3}{4}$	$2\frac{3}{4}$	Do.
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Table 1.--(Continued)

Date	Area treated	Insect	Formula: DDT 1 pound plus accessory materials as indicated	DDT per acre	Spray per acre	Results
				Pints	Pounds	Gallons	
			Xylene 1.5 plus:			
Sept. 12	Wenham, Mass. Mixed hardwoods 3 swaths	Imported pine sawfly	Shell oil 6.5	3	3	Complete kill of caged Anisota larvae
	1 swath		6.5	1	1	Good kill of caged Anisota larvae
20	do.		13	½	1	Practically no kill of caged Anisota larvae
			6.5	½	½	Do.
19	Young red pine plantation 1 swath		3 plus kerosene 3	1	1	Complete kill of caged house-flies
			6.5 plus fish oil 0.25 plus motor oil 0.05	1	1	Do.
			Kerosene 6.5	1	1	Do.
			Kerosene only, 7.5	1	1	Do.

Applications for control of the red-headed pine sawfly were made on June 30 at Brasher, N. Y., on two plots laid out in 9-year-old red pine plantations. The degree of infestation ranged from light to extremely heavy. Hatching had begun on June 18, and was estimated to about 70 percent completed on the day of spraying. One plot was treated at the dosage used on the gypsy moth plots. It was planned to spray the other plot at the rate of 3½ pounds of DDT in 3½ gallons of spray. However, flying conditions caused considerable drift of insecticide, and about 11 acres were covered instead of the 7 acres laid out. The second plot was therefore treated with an average of 2¼ pounds of DDT per acre, but undoubtedly the dosage was considerably lighter on the borders of the area. Since complete control was obtained on both areas, a dosage at least as low as 2 pounds per acre is sufficient for the control of this insect in young plantations.

Three plots heavily infested with the spruce budworm (Archips fumiferana (Clem.)) were treated in Algonquin Park in Ontario, Canada, on June 27. At this time about 90 percent of the insects were in the pupal stage, about 8 percent were moths, and about 2 percent were larvae. Immediately after the application large numbers of the moths, obviously affected by the DDT, were observed fluttering around the bases of the trees, but many that were still in flight appeared to be unaffected. The spray was applied under apparently ideal conditions, although there was some ground fog and the spray settled very slowly. Glass plates placed on the ground showed very poor coverage on all plots. It seemed that this poor coverage was due to the density of the coniferous foliage, particularly near the ground. Some plates with comparatively little foliage immediately over them had a light deposit of DDT crystals. Final results of this work cannot be reported until the spring of 1945, when the young budworms will leave their hibernacula, but it is known that a large population of living larvae went into hibernation.

Treatments against an imported pine sawfly, Diprion frutetorum (F.), were made on four plots at Litchfield on Sept. 16. Although three of these plots were only one swath wide, the larval population was sufficient to indicate the degree of control that could be expected against this species. Very good kill was obtained on a 55-foot swath where 1 pound of DDT per acre was applied in 1 gallon of spray; excellent kill was obtained for a width of 158 feet where 2 pounds of DDT per acre was applied in 2 gallons of spray by laying down two overlapping swaths. The results obtained in the field seemed to be considerably better than those obtained in the laboratory (tests described in following paragraphs), where healthy larvae fed on treated foliage. Possibly this was due to the high percentage of larvae actually hit by the spray at the time of application.

Tests on Dosage and Residual Toxicity

In the fall of 1944 a number of airplane applications were made in order to test the effectiveness of DDT when applied at different dosages

under varying conditions and in different formulas. Four dosages were applied to excellent stands of mixed hardwood at Wendell, Mass., on September 12 and 20 and to well-stocked, 40-year-old red pine plantations at Litchfield on September 16. Four formulas were applied to young red pine plantations at Wendell on September 19. Since it was too late in the season to determine the effect of these treatments under field conditions, foliage from the treated plots was collected and fed to caged larvae of the orange-striped oakworm (Anisota senatoria (A. and S.)) and Diprion frutetorum while they were available. Later houseflies (Musca domestica L.) were used to test the residual toxicity of sprayed foliage. Since the plantations contained considerable oak sprout growth, it was possible to test both coniferous and deciduous foliage collected from them.

Houseflies used in all laboratory tests were placed in clean boxes with foliage from the plots and held under observation for 6 days, being fed daily. As a check on the normal mortality of flies held under these conditions, 4 lots of 10 flies each were held in boxes with untreated oak foliage and a similar number were held with untreated pine foliage. A total of 15 flies, 7 on oak and 8 on pine foliage, or 19 percent of the flies under observation, had died at the end of the 6-day test.

Dosages used on the 40-year-old red pine plantation at Litchfield were identical with those used on mixed hardwood at Wendell, except that 2 pounds of DDT per acre in 2 gallons of spray were used in place of 3 pounds per acre in 3 gallons of spray. Residual toxicity as judged by exposing insects to foliage collected from the various plots indicates rather well-defined results. Mortality of Anisota senatoria was 100 percent when the larvae were fed freshly sprayed oak foliage from the plot treated at the rate of 3 pounds of DDT per acre, but was only 62, 3, and 3 percent when the larvae were fed foliage from plots sprayed at the rates of 1 and 1/2 pound of DDT in 1 gallon of spray, and 1/2 pound of DDT in 1/2 gallon of spray, respectively. Very little foliage was eaten in boxes where the mortality was greatest. In most instances death was apparently caused by contact with DDT crystals. After 6.6 inches of rain, which fell during the hurricane of September 14, Anisota larvae were practically unaffected by foliage from any of the untreated plots.

The mortality of houseflies held in boxes with foliage from the hardwood plots sprayed with 3 pounds of DDT per acre was 100 percent on freshly sprayed foliage, and from 62 to 78 percent mortality on foliage collected over a 72-day period (6 collections). Mortality of flies exposed to freshly sprayed foliage from plots treated with 1 and 1/2 pound of DDT in 1 gallon of spray, and 1/2 pound of DDT in 1/2 gallon of spray per acre was 100 percent but dropped to 30, 10, and 45 percent when foliage was collected after 38, 30, and 30 days, respectively.

Four lots of Diprion frutetorum larvae that were fed foliage from the red pine plantation plots in Litchfield showed no striking differences in mortality (33 to 65 percent). Possibly this was due to the advanced age

of the larvae when they were brought into the laboratory. At least many of them formed cocoons in the boxes. The mortality of houseflies was 100 percent when caged with fresh foliage from all plots. Five collections of foliage, which were made over a 54-day period, from the plot sprayed at the rate of 2 pounds of DDT per acre also caused 100 percent mortality of houseflies. A sixth collection made 70 days after treatment caused 70 percent mortality. The mortality of flies caged with foliage from plots sprayed at the rates of 1 and ½ pound of DDT in 1 gallon of spray and ½ pound of DDT in ½ gallon of spray per acre was considerably less from the first five collections than from the plot sprayed with 2 pounds of DDT per acre, but for the sixth collection, made 70 days after treatment, mortality was 60, 58, and 65 percent, respectively, from the three plots.

DDT mixed in four different formulas (see table 1) was applied at the rate of 1 pound in 1 gallon of spray per acre to the plantation plots of young red pine at Wendell. Foliage collected from these plots showed remarkable residual toxicity to houseflies. Only slight differences in mortality were shown by foliage treated with the different formulas. The foliage from the plot treated with DDT in kerosene, with no other solvent, was not quite so toxic as that from the other plots. When houseflies were caged with foliage from some of the plots, mortality was 100 percent up to 45 days after application, but after 65 days mortality was decidedly lower on foliage from all plots.

The weather was very humid when these sprays were applied; so little was learned regarding the evaporation of the different sprays during application. The sprays appear to have adhered to pine foliage somewhat longer than to oak foliage.

PRESENCE OF DDT IN A RESERVOIR DUE TO TREATMENT OF WATERSHED

A 40-acre watershed of deciduous growth, surrounding a 3-acre reservoir in Pittston, Pa., was treated at the rate of 5 pounds of DDT in 5 gallons of spray per acre to determine the amount of DDT present in the reservoir after rain. The forest cover of the area is largely scrubby second growth varying from moderately well-developed white oak and red maple to scrub oak barrens. Chestnut oak is prominent on some portions of the area. The capacity of the reservoir is about 3½ million gallons.

The area was treated on August 14. Sufficient spray drifted onto the surface of the water so that a close speckling of oil droplets was plainly visible. Within a few hours this oil film had been blown to one end of the reservoir. There was a precipitation of 0.27 inch on the evening of August 14 and 0.46 inch on August 16. On August 17, and again on November 16, composite water samples were taken from the reservoir and from the water tap in a rendering plant nearby, which draws water for its boilers directly from the reservoir. Samples of surface mud were taken from the margins of the reservoir on August 14 and 16. All these samples were tested for DDT in the Division of Insecticide Investigations. The water samples contained less than 1 part of DDT per 100 million parts of water. The mud contained less than 1 part per million and probably well below this figure, but it was impossible to establish a limit lower than this.

EFFECT OF DDT ON FOREST FAUNA

Because of the high toxicity of DDT to insect life in general, and its possible direct and indirect effect on wildlife, its application to forested areas must be carefully and intensively studied. H. K. Townes and Neil Hotchkiss made observations on the watershed at Pittston at the time that area was treated (Aug. 15), and they visited the 20-acre plot at Jefferson, Pa., which had been treated on May 3. A great deal of information was obtained, which will be of great help in planning intensive studies for the 1945 season.

At the time the 20-acre plot at Jefferson was treated, it was observed that mosquitos and black flies were practically eliminated from the area. On June 7 a large dragonfly and a bumblebee, both obviously affected, were observed. When Doctor Townes visited the area he noted the presence of a rich and varied fauna of all species of insects that one would expect in that type of woods. Of course, the area treated is not extensive; so it was impossible to judge what part of the fauna was from survivors in the sprayed area and what part had migrated from the adjacent untreated area. Various insectivorous birds in considerable numbers were also observed.

Observations at Pittston indicated that the DDT had severely reduced the abundance of most of the terrestrial insects, but 5 days after the application enough specimens of most of the species survived to repopulate the area. There was a high mortality of adults of several species of aquatic insects, which were on or near the surface of the reservoir, and some mortality of immature Hemiptera that breathe at the surface of the water. The insects living at the bottom of the reservoir were apparently unaffected.

There was no indication of mortality among the bird life of the forest, but owing to the mobility of the bird population at the time of the spraying it cannot be concluded that there were no effects. Other vertebrate life seemed unaffected on the day the spray was applied, but the next morning about 25 dead or dying bullfrogs (Rana catesbiana Shaw), 1 dead tadpole, 10 dead or dying sunfish (unidentified), and 2 dead golden shiners (Notemigonus crysoleucas (Mitchell)) were found at the water's edge. Numerous dead leopard frogs (Rana pipiens Schreber) (not aquatic but in the rank vegetation at the water's edge) were also found. Wood frogs (Rana sylvatica LeConte) and spring peepers (Hyla crucifer Wied.) were moderately numerous in the damper part of the woods. None were seen alive after the spray was applied, but only 1 was found dead. Dissections indicated that the frogs had fed heavily on species of aquatic insects that had been killed by the insecticide. Whether it was the poisoned insects or skin contact with the spray that killed the frogs and fish was not determined. Both fish and frogs were still common on August 18, 4 days after application of the DDT.

SUMMARY AND CONCLUSIONS

Experiments with DDT for the control of certain forest insects were conducted by applying the sprays with ground and aerial equipment. Complete control of the gypsy moth (Porthetria dispar (L.)) was effected on small experimental plots when light dosages in an emulsion were applied by means of ground equipment either just before the eggs hatched or during the larval season. Very promising results were obtained when DDT was distributed from airplanes, although experimental work in 1944 was rather limited. A White Standard Biplane equipped with a spinner-disk distributing apparatus was used in treating all plots except one, which was sprayed with a Piper Cub plane. The DDT in oil sprays was distributed as a finely atomized mist. Good coverage by the insecticide was obtained in mixed hardwood growth when 3 gallons of spray were applied per acre, and in young plantations with 1 gallon per acre, but gallonage must obviously be varied according to the area, density, and type of foliage to be covered.

Complete control of the gypsy moth with spray applied just before hatching of the eggs and after larvae were partly grown, and of the green-striped maple worm (Anisota rubicunda (F.)) when larvae were partly grown, was obtained by using 5 pounds of DDT in 5 gallons of oil per acre. Complete control of the red-headed pine sawfly (Neodiprion lecontei (Fitch)) was obtained at this dosage, and also at about 2 pounds of DDT in 2 gallons of oil per acre. An imported pine sawfly, Diprion frutetorum (F.) was also effectively controlled at 2 pounds of DDT per acre.

In treatments applied from the airplane against the gypsy moth, the green-striped maple worm, and the red-headed pine sawfly, the spray was mixed at the rate of DDT 1 pound, cyclohexanone 1 pint, and Shell horticultural spray base heavy oil about 7 pints (enough to equal 1 gallon of mixed spray). In the treatments against the imported pine sawfly 1½ pints of xylene were substituted for 1 pint of cyclohexanone and the solution seemed perfectly satisfactory. In the treatments against the spruce budworm (Archips fumiferana (Clem.)) the spray was mixed at the rate of DDT 1 pound, cyclohexanone 1 pint, and Mentor No. 29 oil 6½ to 14 pints depending upon the volume of spray applied per acre.

Late in the season four formulas differing only slightly in composition were applied to young red pine plantation plots. In three of them kerosene was substituted wholly or in part for the horticultural oil and in the fourth small amounts of fish oil and motor oil were used. Xylene was used as a solvent in three of the formulas, and kerosene with no other solvent in the fourth. All these formulas had long residual toxicity and seemed promising.

The 40-acre watershed of a small reservoir in Pittston, Pa., was treated at the rate of 5 pounds of DDT in 5 gallons of oil per acre. Three days later, after 0.75 inch of rain had fallen, an analysis of water samples from the reservoir indicated less than 1 part of DDT in 100 million parts of water. In the same area limited observations were made on the effect of DDT on forest fauna in general. There was no evidence of mortality of bird life, but some of the fish and bullfrogs in the reservoir were killed. Most species of insects were greatly reduced in number, but 3 days after the spray had been applied enough specimens of most species remained to repopulate the area.

It is believed that the experimental work with DDT in 1944 warrants an optimistic attitude toward its use in the future. Many difficulties must be solved, but it appears that DDT can be used as a spray from aircraft at such low dosages that it will be practical to use it as a control measure against certain forest insects.

Figure 1.--White standard biplane distributing an oil spray containing DDT with the spinner disk type of apparatus over woodland at Wendell, Mass.

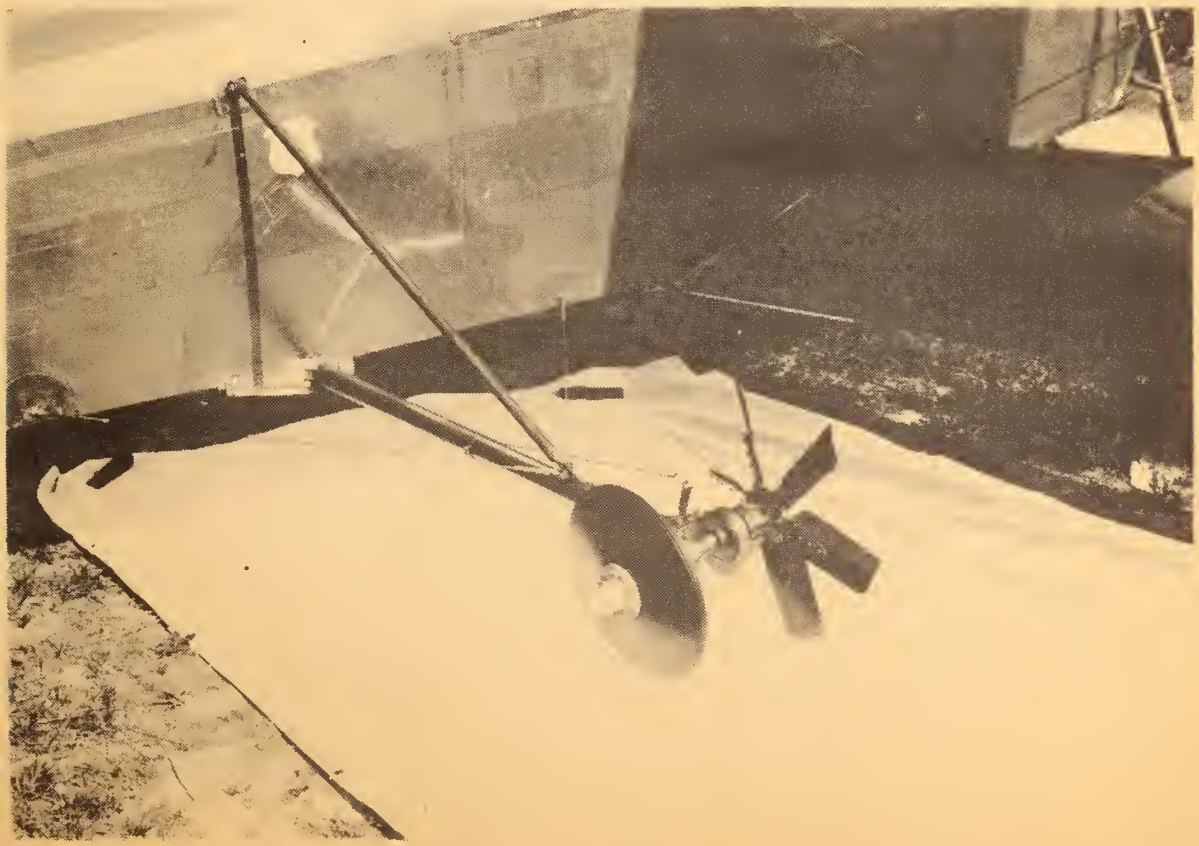

Figure 2.--Right-hand unit of spinner-disk distributing apparatus.